# ECONOMIC OPERATION OF POWER SYSTEMS


Dr. Ahmed Mohamed Azmy

Department of Electrical Power and Machine Engineering

Tanta University - Egypt

Faculty of Engineering

Tanta University

Title: **Generation and economy of electrical energy**

Code: **EPM3110**

Lecture: **3** Tutorial: **3** Practical: **--** Total: **6**

## Weighting of Assessments

| | |
|---|---|
| **Mid-Term Examination** | **10 %** |
| **Final-term Examination** | **60 %** |
| **Oral Examination.** | **20 %** |
| **Practical Examination** | **0.0 %** |
| **Semester Work** | **10 %** |
| **Total** | **100%** |

## Overall Aims of Course

**The course aims at providing the basic knowledge required by practicing engineers for dealing with economics and operation of power systems to:**

- Realize the different load curves and factors used in defining the loading conditions of power system.
- Recognize the operating tariffs of electrical energy and selecting the most proper one depending on the load profile.
- Enhance the economic operation of power systems to achieve the minimum cost operation under different loading conditions.
- Encourage dealing with main types of power plants including conventional and non-conventional types

## Intended Learning Outcomes of Course (ILOs)

### a. Knowledge and Understanding

- a1- Describe the Egyptian electrical network
- a2- Identify the development of energy utilization in recent decades
- a3- Enumerate the characteristics of different loads
- a4- Outline the concepts of investment and depreciation in power system
- a5- Mention the benefits of economic operation of power systems
- a6- State the main differences between electrical power plants

## b. Intellectual Skills

- **b1- Differentiate between various curves and factors describing different types of loads**
- **b2- Distinguish the methods used to define the operating tariffs of electrical energy.**
- **b3- Predict the situations where the transmission losses have to be considered and where they have to be omitted.**
- **b4- Develop mathematical models of the optimization problem and analyze the problem to find the suitable solution.**
- **b5- Choose the suitable type of power plants depending on their features, and technical and economical conditions**

## c. Professional and Practical Skills

**c1- Use load curves to extract useful information.**

**c2- Utilize the operating factors to find out required information**

**c3- Apply different electricity tariffs.**

**c4- Solve the economic dispatch problem.**

**c5- Apply suitable formulas to calculate the fixed costs as well as running costs of major types of power plants**

## d. General and Transferable Skills

**d1- Learn how to collect suitable data about the economic dispatch problem**

**d2- Cooperate to process the collected data.**

**d3- Accomplish tasks within time.**

# List of References

## Course Notes

- Azmy Ahmed, "Economic operation of power systems"

## Essential Books (Text Books)

- William D. Stevenson, Elements of power system analysis

## Recommended Books

- Knable, A., Electrical power systems engineering

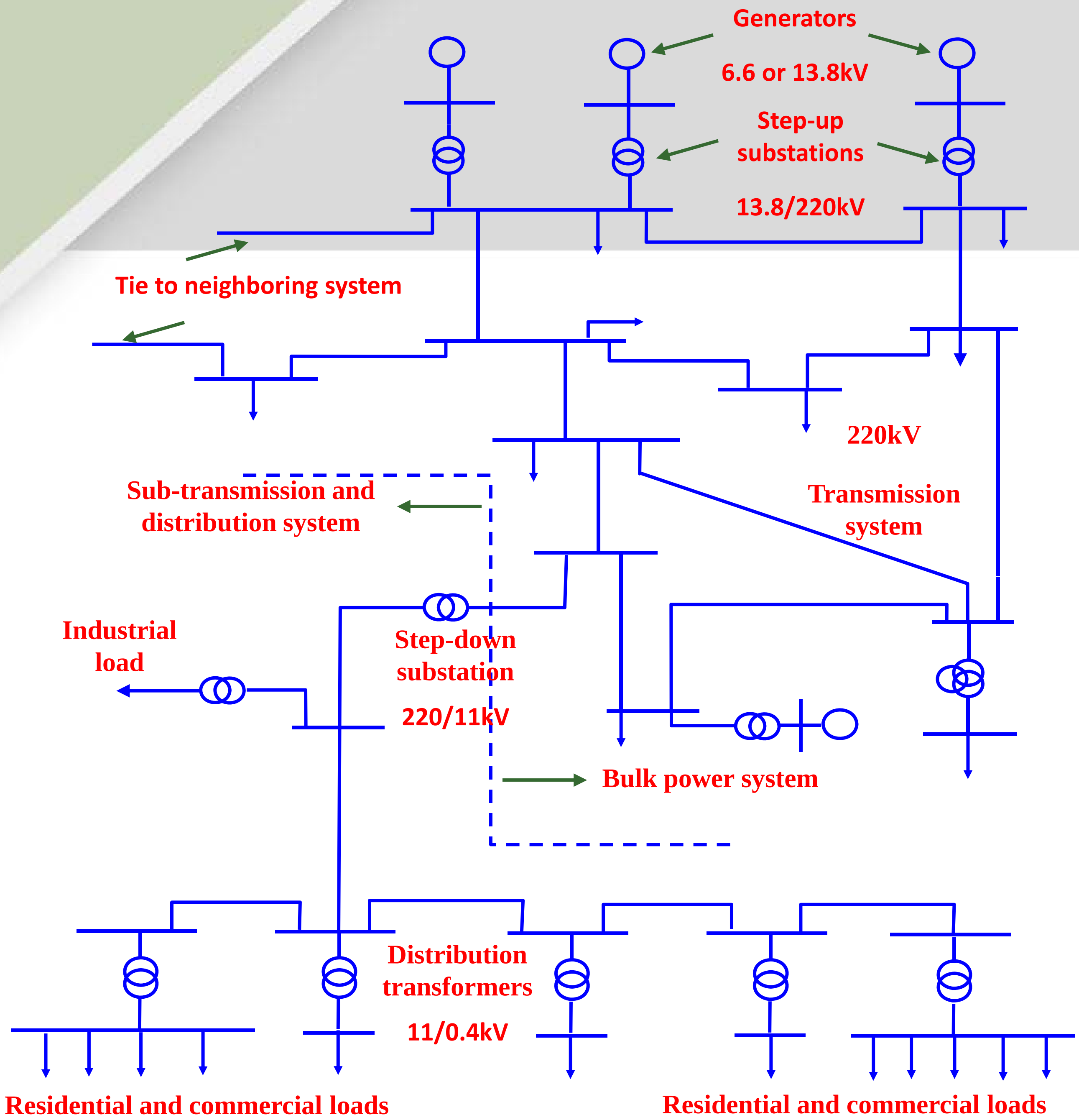
# List of References


- R. Bergen and V. Vittal, “Power System Analysis”, Prentice-Hall, 2005
- Hadi Saadat, “Power system Analysis”, McGraw Hill WCB, 2nd Edition, 2002
- Tyler G. Hcks "Power Plant Evaluation & Design Reference Guide". McGrew Hill Book Co., 1985
- H.P. Garg et al., “Solar Energy Fundamentals and Applications”, MC Graw Hill Co., 1997
- John J. Grainger and William D. Stevenson, Jr, "Power System Analysis", McGraw-Hill Inc, 1994
- Kovarik, Tom, Charles Pupher, and John Hurst, “Wind Energy” Domus Books, 1979.

# List of References


- Skortzki R.G. and Vopat, W.A "Power Plant Engineering and Economy", McGrew Hill Book Co., 1996
- Bernhardt G.A.Skrotzki and William A. Vopat, “Power station Engineering and Economy”, Tata McGraw Hill Publishing Company Ltd., New Delhi, 1960
- Stocker, W. F. "Design of Thermal Systems". McGraw Hill Book Co., 1992
- Hunt, Daniel V. Windpower, “A Handbook on Wind Energy Conversion Systems” Van Nostrand Reinhold, 1981.
- Wood ,A.J. and Woolenberg B.F., “power generation, operation and control” John Willey 1984

# INTRODUCTION AND GENERAL BASICS OF POWER SYSTEMS


Generators
6.6 or 13.8kV
Step-up
substations
13.8/220kV
Tie to neighboring system
220kV
Transmission
system
Sub-transmission and
distribution system
Industrial
load
Step-down
substation
220/11kV
Bulk power system
Distribution
transformers
11/0.4kV
Residential and commercial loads
Residential and commercial loads

# Egyptian network: an overview

About 32 bus-bars
32 power stations
24 GW installed electric capacity

About 85% of the electric generating capacity is from thermal stations, i.e. gas power stations, while the Aswan High Dam provides about 15% of the total generated power.

# Largest Power Plants in Egypt

| Power Station | Capacity (MW) | Fuel Type |
|---|---|---|
| Aswan High | 2,100 | Hydraulic |
| Shoubrah El Kheima | 1,350 | Oil |
| El-Kureimat | 1,300 | Gas |
| Damietta | 1,200 | Gas |
| Cairo West | 1,100 | Gas/Oil |
| Ataka | 950 | Oil |
| Abu Qir | 930 | Gas/Oil |
| Cairo South | 814 | Gas/Oil |
| Damanhour | 678 | Oil |
| Aswan | 622 | Hydraulic |

# Effect of *high voltage* transmission

- The transmitted current is decreased,
- The total power loss in the network is decreased,
- The efficiency of the transmission line is increased,
- The voltage drop is decreased,
- The voltage regulation is decreased,
- The cross section area of the conductors is decreased, and
- The total cost of the copper is decreased

# Standard voltages

| | |
|---|---|
| **Generating voltages:** | **6.6, 11, 13.8, 15.75 and 33 kV** |
| **High-voltage transmission:** | **10, 11, 22, 33, 66, 110, 132, 154, 220, 380, 500 and 750 kV** |
| **Low-voltage transmission:** | **6.6 and 11 kV** |
| **Distribution voltages:** | **0.4 kV** |

# Optimal cross section area of conductors

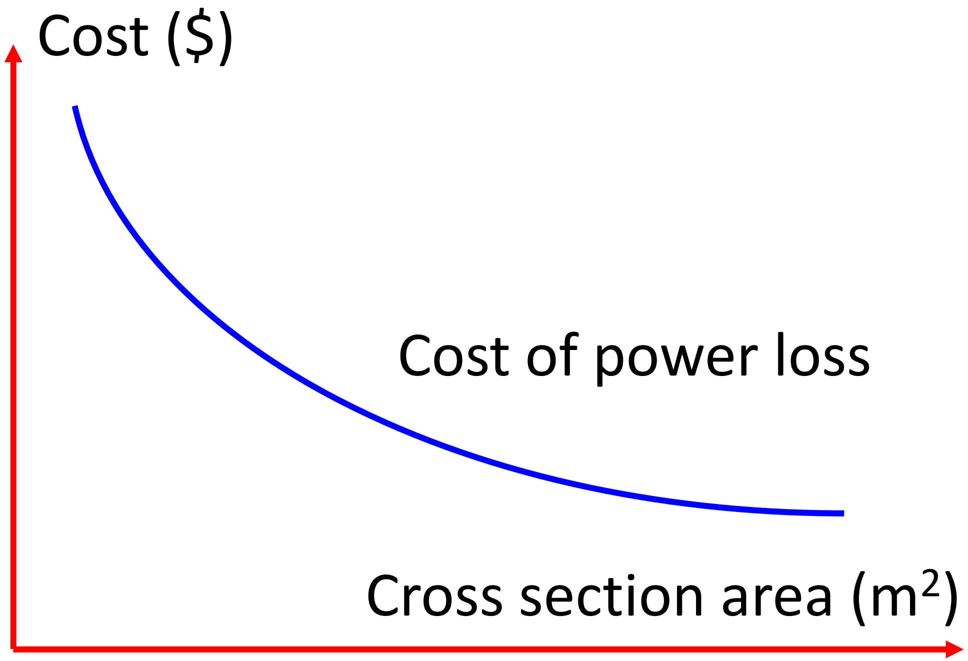
The energy wasted in a transmission line:

$$W = \frac{I^2 \cdot R \cdot T}{1000} \quad \text{kWh}$$

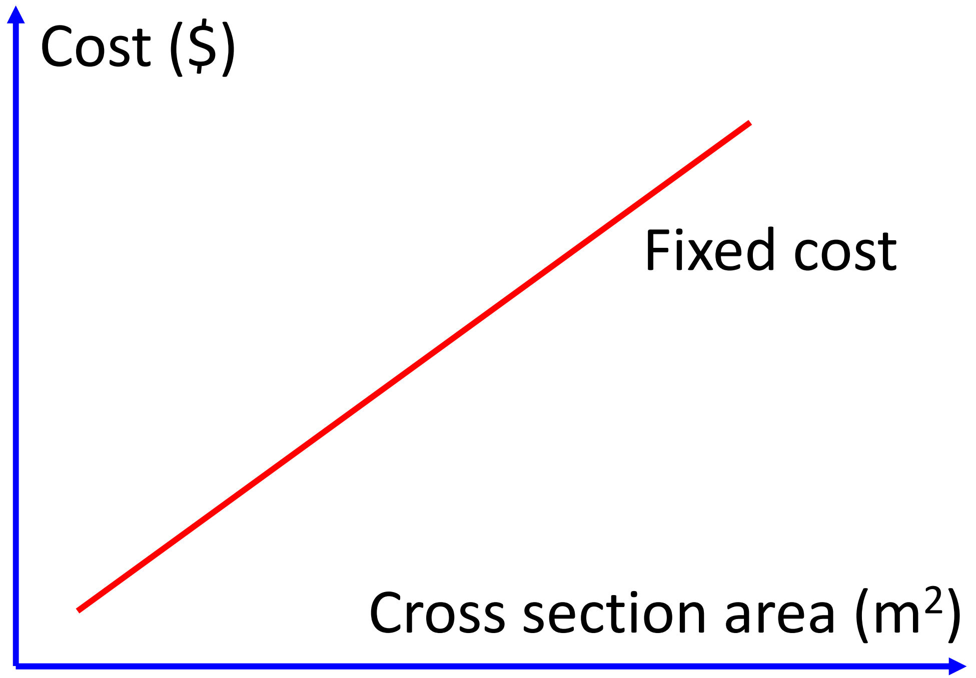
With the tariff of kWh is "c" (L.E. / kWh), the cost of lost energy is

$$C_{Le} = c\frac{I^2 \cdot R \cdot T}{1000}$$

$$= c\frac{I^2 \cdot \rho \cdot L.T}{1000\, a} = \frac{K_1}{a}$$



# The fixed cost of the conductor $C_f = K_2.a.D$



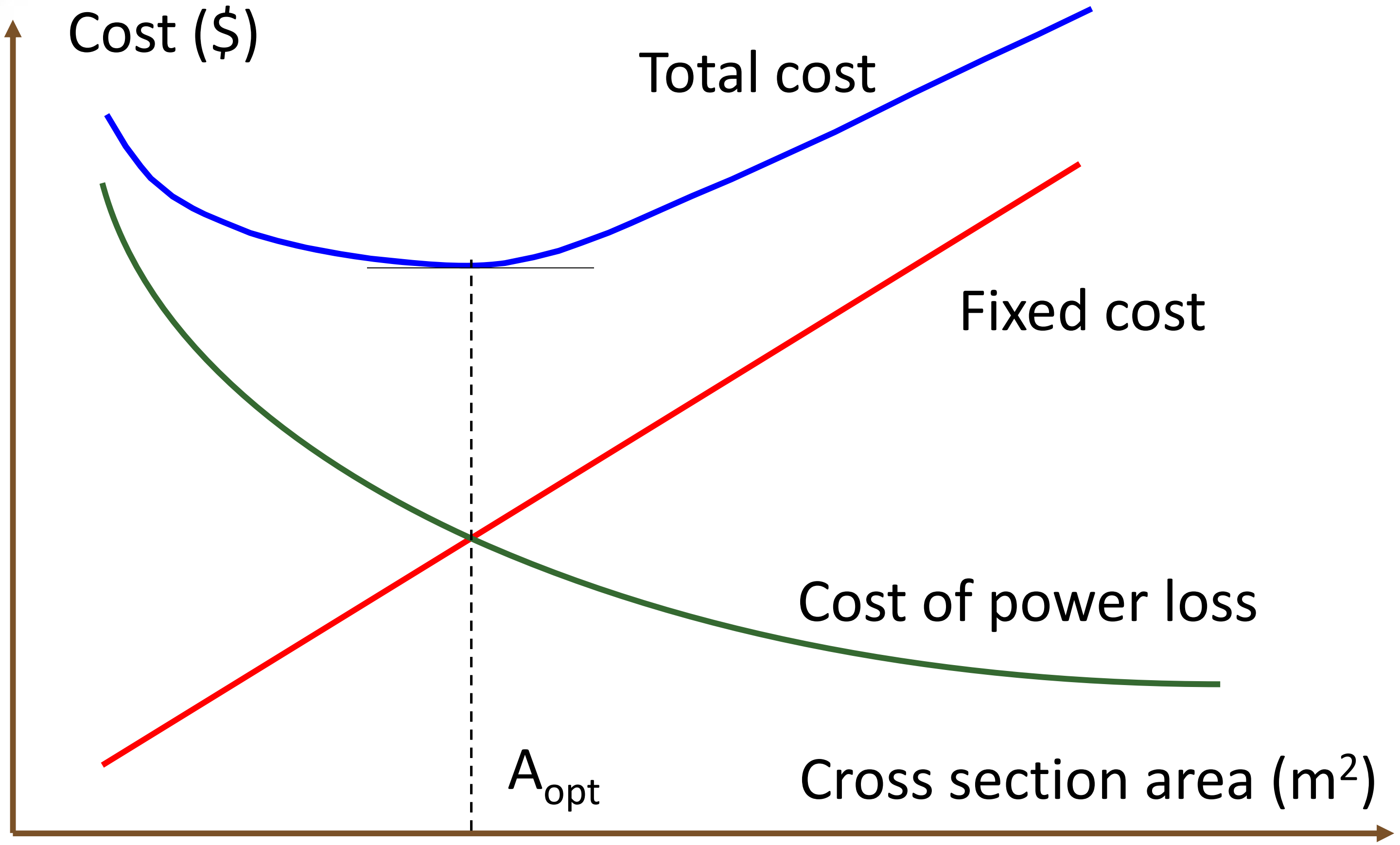

$C_f$ is the fixed cost and
D is the annual interest and depreciation

## The total cost

$$C_{tot} = \frac{K_1}{a} + K_2 \cdot a \, .D$$

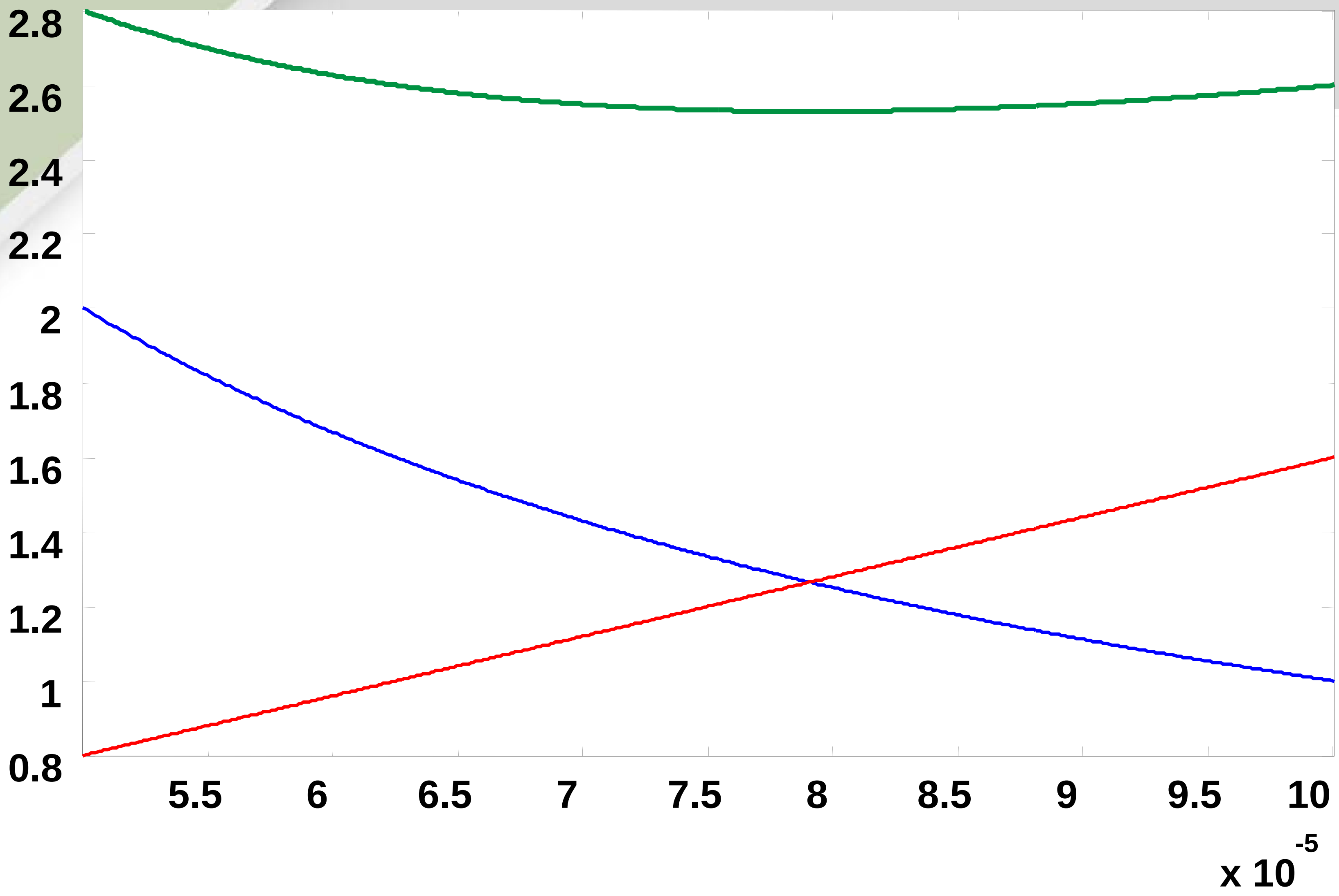
## For minimum cross section area:

$$\frac{\partial C_{tot}}{\partial a} = 0 \Rightarrow -\frac{K_1}{a^2} + K_2 \cdot D = 0 \Rightarrow a = \sqrt{\frac{K_1}{K_2 \cdot D}}$$



# Applications

Taking the values of the constants for a certain cable as follows: $K_1=10^{-4}\$m^2$, $K_2=2*10^5\$/m^2$ and D=8%, write a MATLAB program to illustrate the variation of both the fixed and running costs with the cross section area of the cable. The figure has to include the total-cost curve. The area varies from 50 up to $100mm^2$


2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
x 10^-5

# Load curves

Planning and economic investigation of power systems are based on many curves that describe the load variation

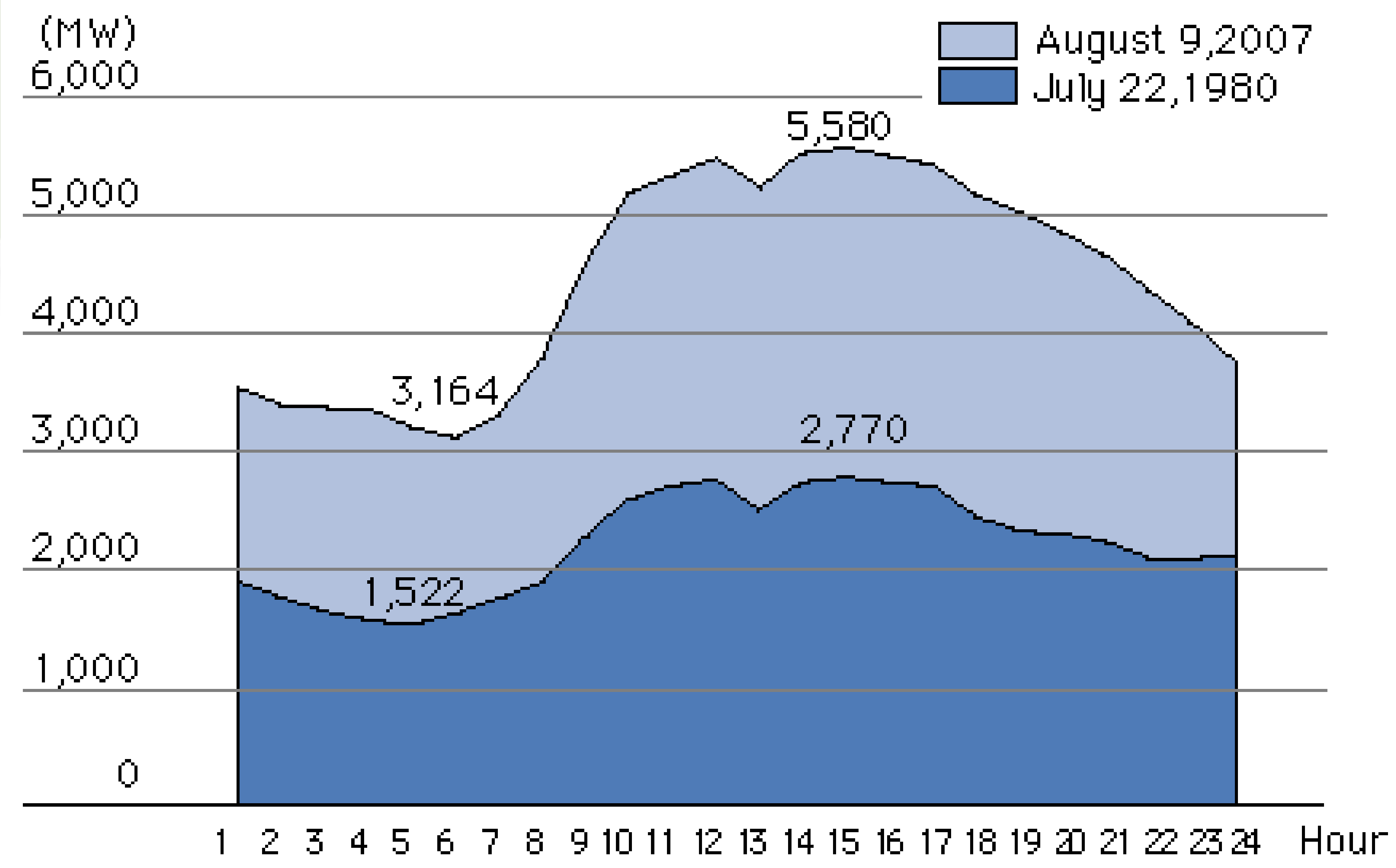
- Daily Load curve
- Duration curve
- Energy Curve

# The daily load curve

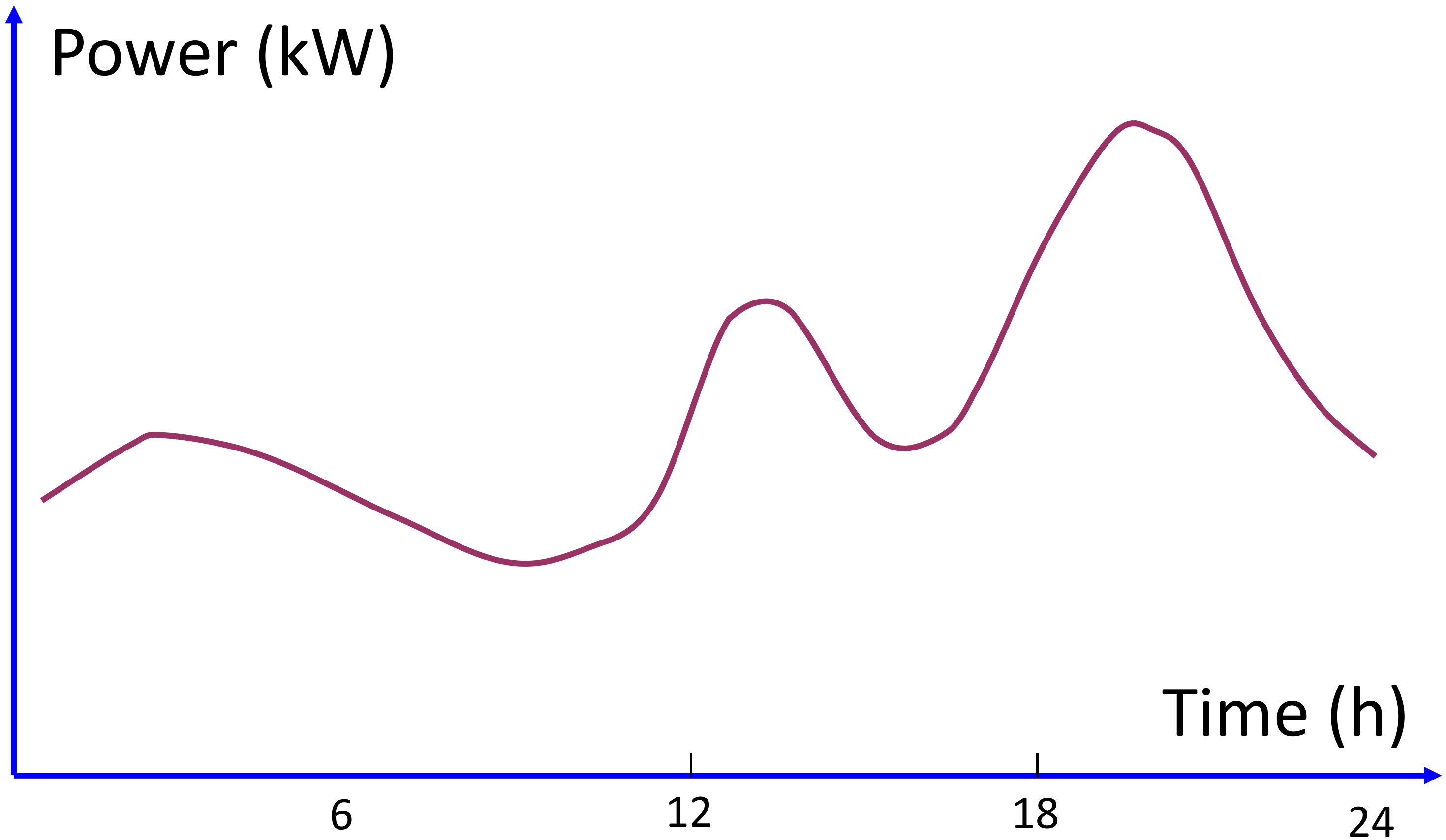
The curve describing the variation of the supplied power to a certain load with time through one day is known as the daily load curve of this load

Similarly, weekly, monthly and yearly (annual) load curves can be plotted

# The daily load curve

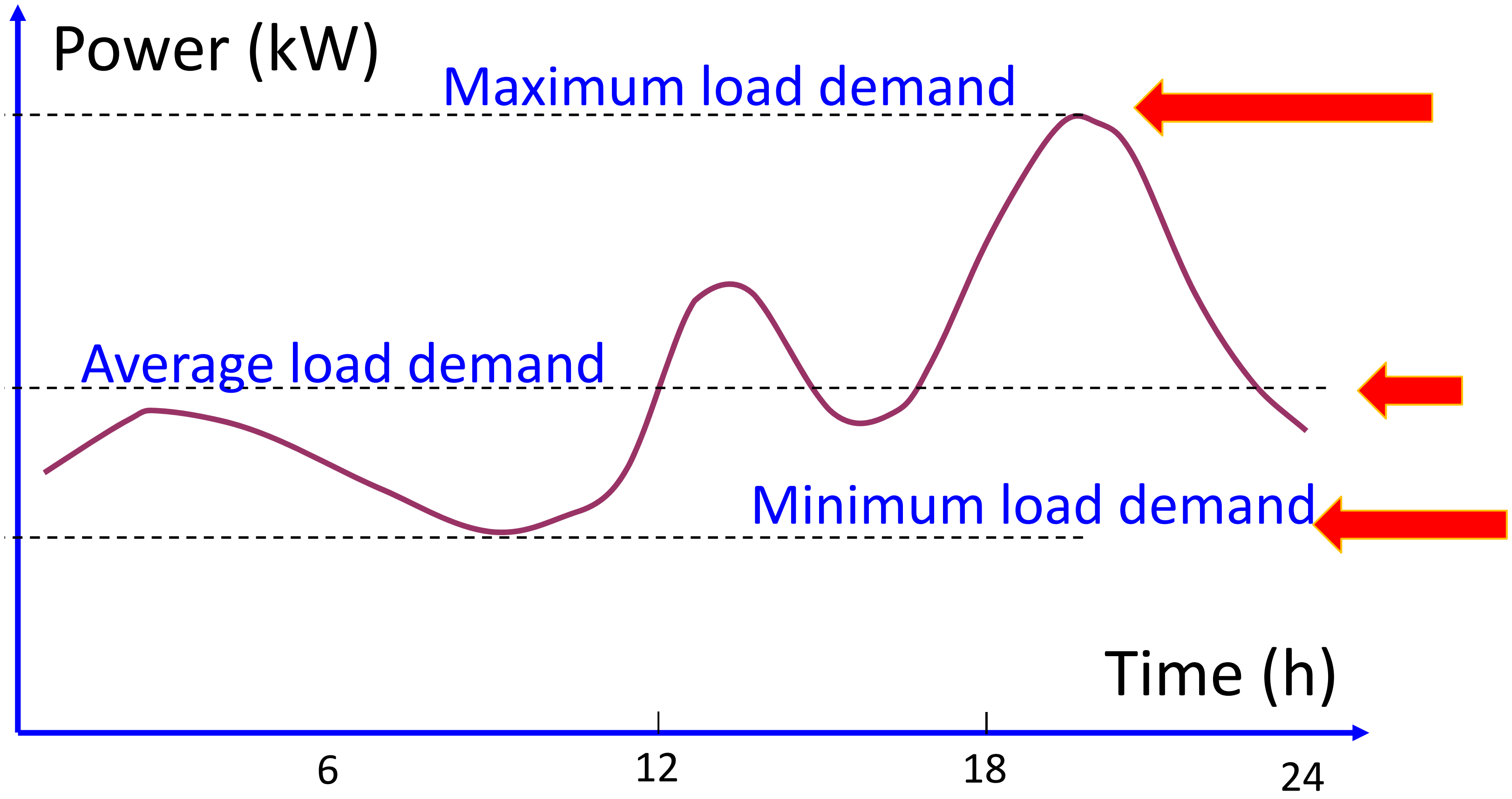


# The daily load curve



# The daily load curve

From this curve, useful information can be obtained



# The daily load curve

- The maximum load demand is obtained from the daily load curve by recording the peak value of the power
- The area under the daily load curve is the **consumed energy** during this day
- The average consumed power is obtained by dividing the consumed energy by the time duration

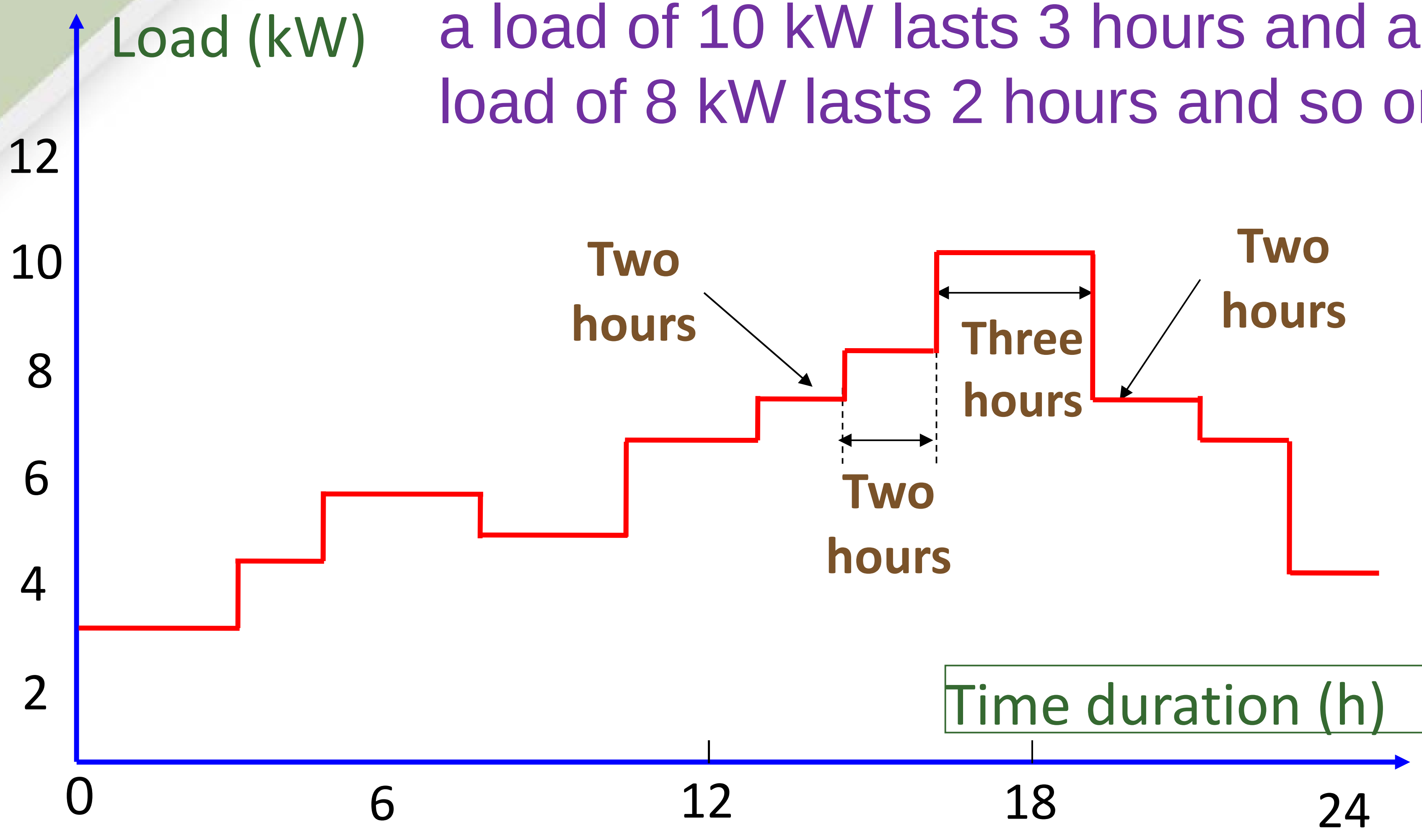
# The daily duration curve

The load duration curve illustrates the variation of a certain load in a **downward** form such that the greatest load is plotted in the left and the smallest one in the right

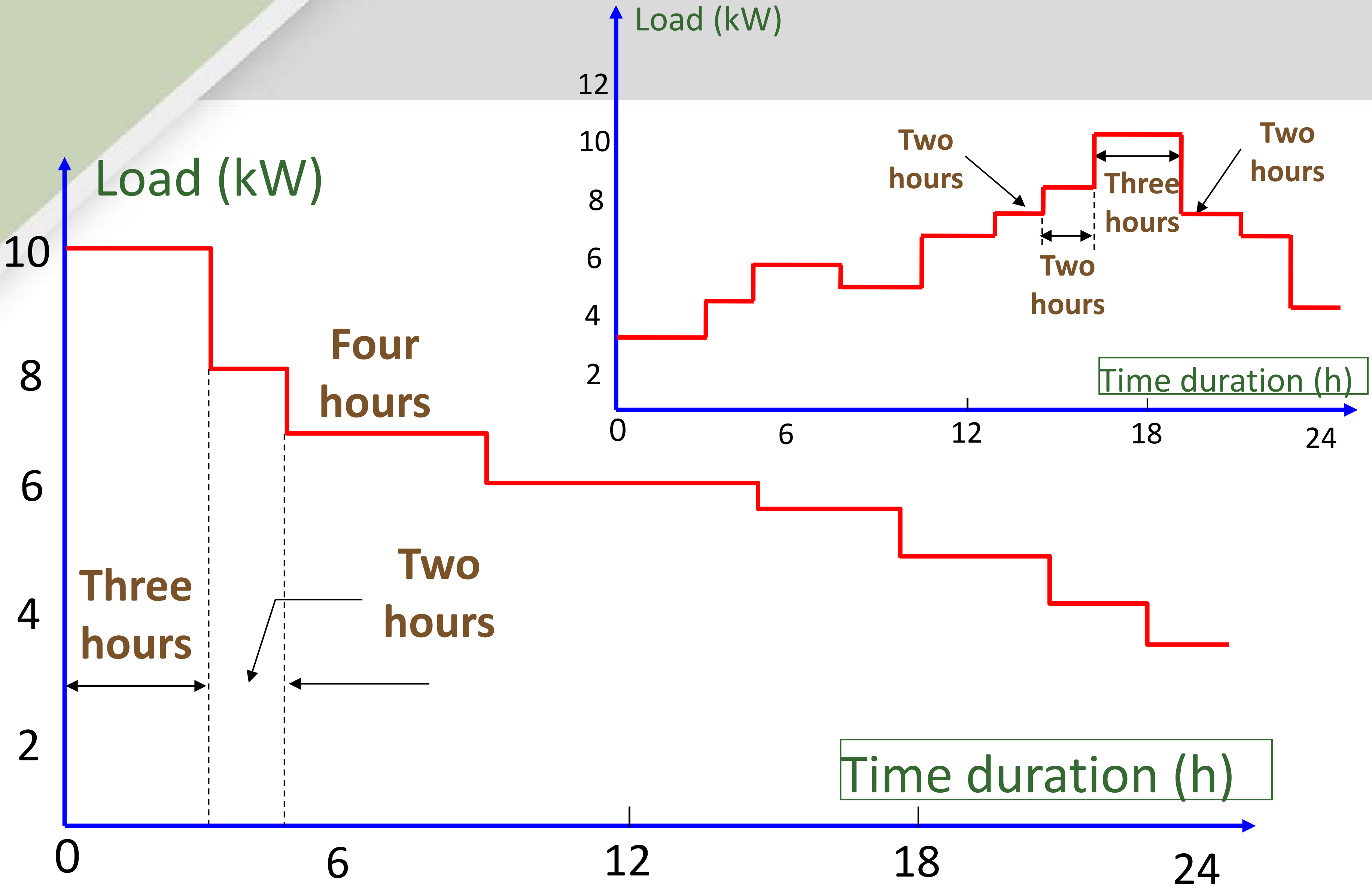
On the time axis, the time duration for which each certain load continues during the day is given

# The daily duration curve

From the figure, we can recognize that a load of 10 kW lasts 3 hours and a load of 8 kW lasts 2 hours and so on

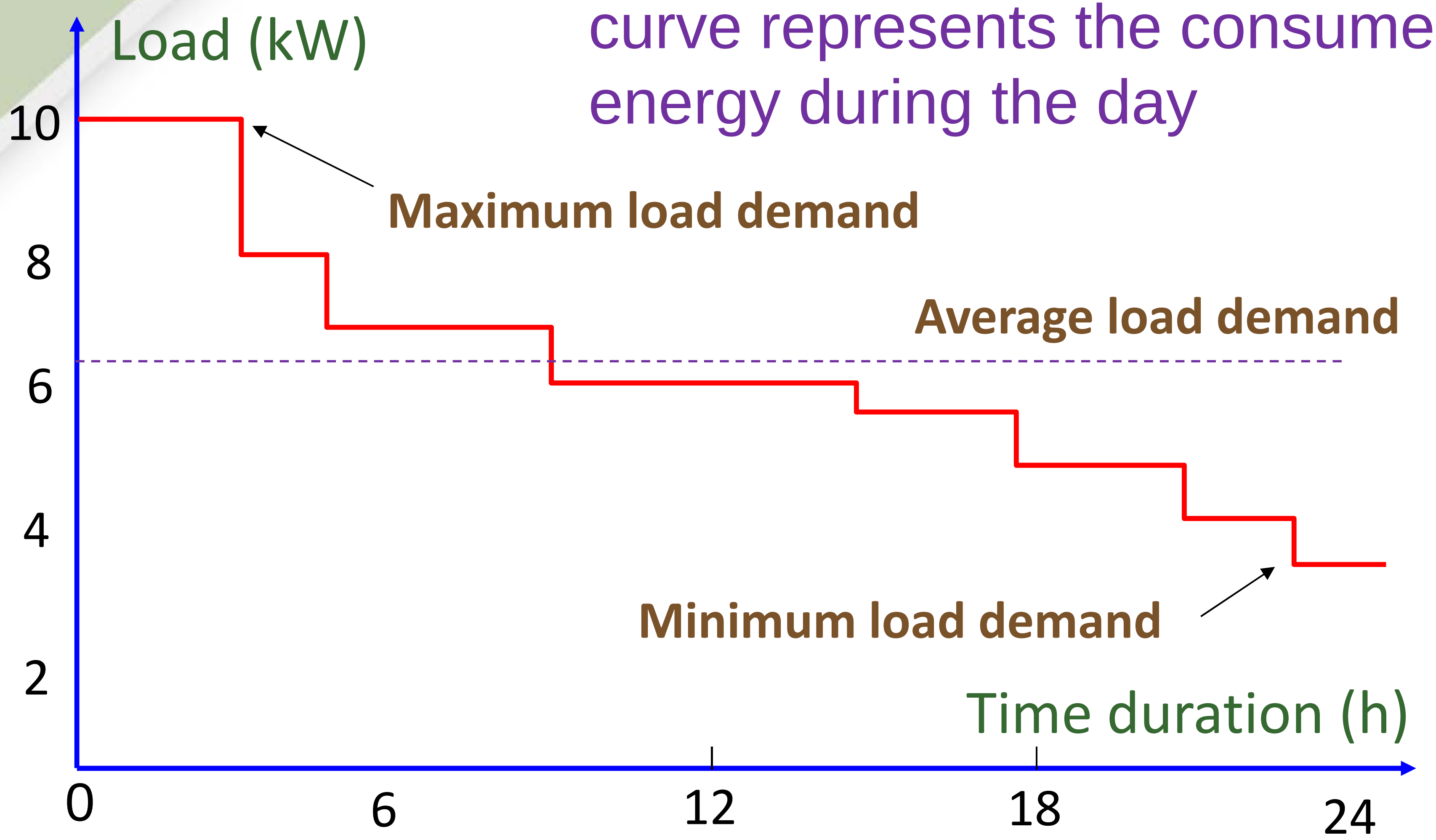


# The daily duration curve



# The daily duration curve

the area under the load duration curve represents the consumed energy during the day



# The Load Energy curve

This curve is derived from the daily load curve

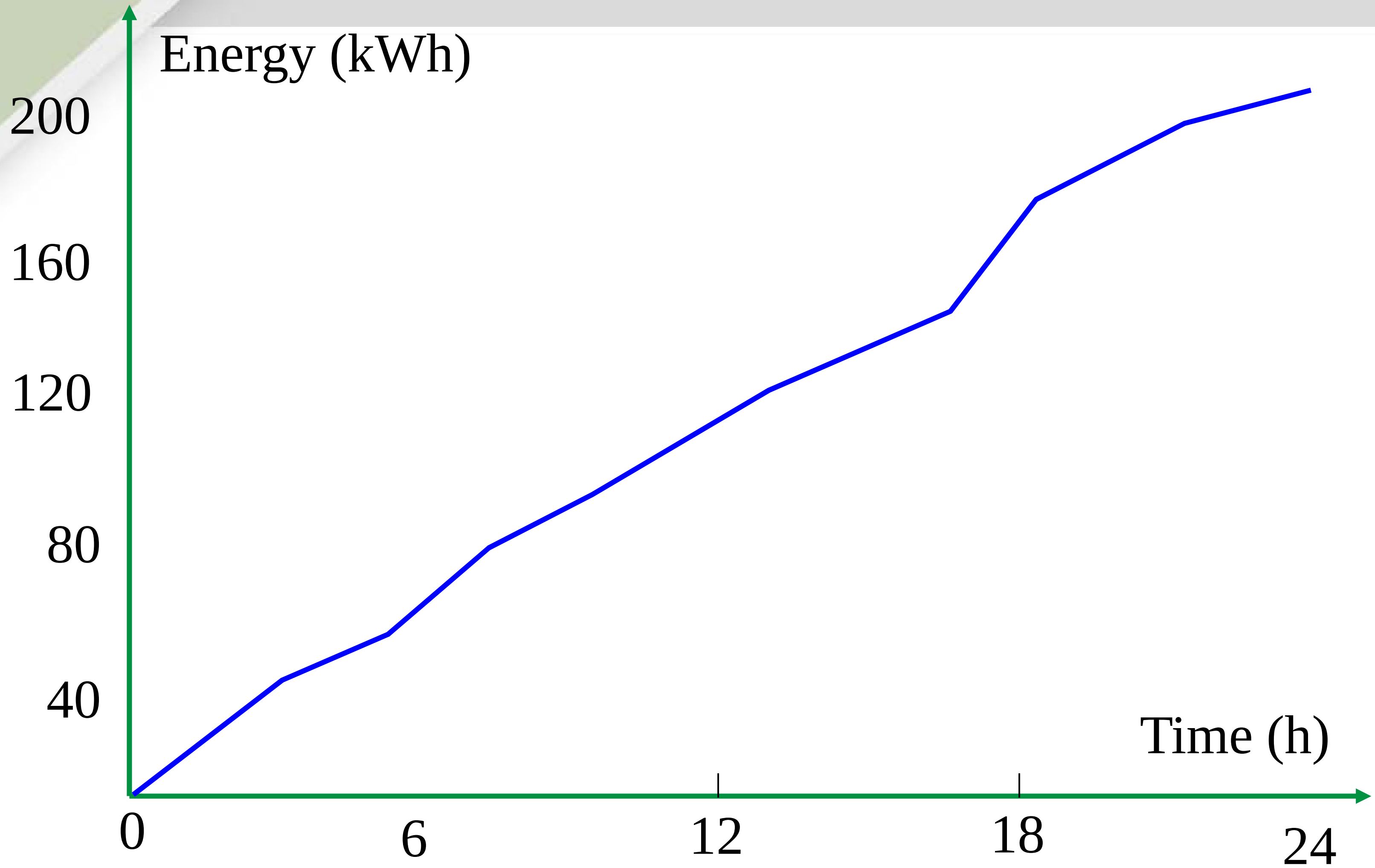
At each time interval, the area under the curve is calculated from the zero time interval until the present time interval

For example, the area under the curve is calculated for each hour and is added to the previous total area to get the energy at the present hour

The curve begins always from energy of zero and increases with time

It is not possible for the energy to decrease with time

# The Load Energy curve



# The Load Energy curve